

Cadomin Reclamation Research Project - Third, Fourth and Fifth Year Results



Alberta
ENERGY AND
NATURAL RESOURCES
Forest Service

CADOMIN RECLAMATION RESEARCH PROJECT
THIRD, FOURTH AND FIFTH-YEAR RESULTS

by

M.R. Islam

S.K. Takyi

1984
Edmonton

ENR Technical Report Number: T/56
International Standard Book Number: 0-86499-122-3

FOR ADDITIONAL COPIES OF THIS REPORT, CONTACT:

Alberta Energy and Natural Resources
Information Centre
Main Floor, Bramalea Building
9920 - 108 Street
Edmonton, Alberta, Canada
T5K 2M4

Telephone: (403) 427-3590

Other titles in this set include:

ENR Report No. 121 - The Cadomin Reclamation Research Project First
Year Results (1978)

ENR Report No. 155 - The Cadomin Reclamation Research Project Second
Year Results (1979)

ABSTRACT

This report summarizes the results for the third, fourth and fifth growing seasons (1980-82) of reclamation experiments on an abandoned mine spoil in a subalpine area. Plant cover developed in the initial two years following sowing improved steadily in the succeeding maintenance fertilization years in all cultivated legumes and grass species tested except alsike clover and sweet clover which by the end of the fifth year had almost disappeared. Timothy, Kentucky bluegrass (Park) and sweet clover did not maintain the high ground cover exhibited during the initial years as compared with other species.

Most species achieved higher cover and biomass production and generally did better on spoil topdressed with a mineral soil than on raw spoil.

The performance of alfalfa, brome grass, creeping red fescue and Kentucky bluegrass (Park) in the third through the fifth years indicated they are better adapted to the site. Dry matter yields specifically of grass species decreased and their vigor deteriorated in the fifth year as the annual maintenance fertilization was stopped in that year. Alfalfa maintained the best growth even when fertilizers were withdrawn in the fifth year. Alfalfa should be considered a good legume in a seed mixture for operational reclamation in similar environments.

Virtually no plant growth occurred on the unfertilized raw spoil seeded to a grass-legume mix during the five-year period. There was, however, some growth upon topdressing with no fertilization.

A steady increase in plant growth was generally achieved over the years when the spoil was topdressed with a mineral soil and fertilized. The highest N-P-K fertilizer rate (kg/ha) 80-40-80 provided the best plant cover on spoil and topdressed spoil. There were no statistically significant differences between single and split applications of the 80-40-80 fertilizer rate.

Seeding rates ranging from 30 to 120 kg/ha did not show any significant effects on the overall percent plant cover and plant performance. The 60 kg seeding rate gave the best results but for economic reasons the 30 kg rate should be preferred.

In the fifth year when fertilization was discontinued, plant growth decreased somewhat. Analyses of the growth media and the plant material relate the causes to deficiency in available nutrients, especially N and P.

Key Words

Fertilization, plant cover, mine land reclamation, revegetation.

TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. STUDY AREA	3
2.1 Location and Physiography	3
2.2 Climate and Weather	3
2.3 Site Vegetation	4
2.4 Soil and Spoil	4
3. MATERIALS AND METHODS	5
3.1 Establishment of Field Trials	5
3.2 Precipitation and Windspeed Measurements	5
3.3 Agronomic Species Adaptability Trials	5
3.4 Agronomic Species Seed-Mix, Seeding Rates and Fertilizer Rates Trials	7
3.5 Assessment Methods	8
3.5.1 Plant Cover	8
3.5.2 Biomass Production	9
3.5.3 Vigor, Thatch Accumulation and Seedhead Production	9
3.5.4 Species Occurrence, Dominant Species, Seed Dominance, and Seed Viability	9
3.5.5 Physical and Chemical Analyses of Spoil, Soil (Topdress) and Biomass	10
a) Physical	10
b) Chemical	10
3.5.6 Data Analyses	11
4. RESULTS AND DISCUSSION	12
4.1 Spoil and Topdressing Characteristics	12
4.2 Precipitation	16
4.3 Snow Cover and Prevailing Winds	17
4.4 Species Adaptability Trials	19
4.5 Seeding Rates and Fertilizer Rates Trials	29
5. CONCLUSIONS	46
LIST OF REFERENCES	48

LIST OF FIGURES

Figure	Page
1. Infiltration Rate on Spoil and Topdressed Plots	13

LIST OF TABLES

Table	Page
1. Antecedent and Saturated Moisture Content (%) of Materials ...	14
2. Some Physical and Chemical Properties of the Spoil and Mineral Soil (used as a Topdressing).....	15
3. Precipitation During Growing Seasons at the Experimental Site	18
4. Percent Plant Cover from 1980 to 1982	21
5. Aerial Biomass Production in 1981	22
6. Seedhead Production	24
7. Plant Vigor	25
8. Nutrient Levels in four Selected Species Treatment Plots (1982)	26
9. Thatch Accumulation (1980)	27
10. Percent Germination of Seeds Collected in October, 1981	28
11. Effects of Seeding and Fertilizer Rates on Percent Plant Cover on Spoil (1980 to 1982)	30
12. Effects of Seeding and Fertilizer Rates on Percent Plant Cover on Spoil Topdressed with Mineral Soil (1980 to 1982) ...	31
13. Effects of Seeding and Fertilizer Rates on Biomass Production (gm/0.25m ²) on Spoil	32
14. Effects of Seeding and Fertilizer Rates on Biomass Production (gm/0.25m ²) on Spoil Topdressed with Mineral Soil.....	33
15. Effects of Fertilizer Rates on Seedhead Production	34
16. Effects of Seeding and Fertilizer Rates on Vigor on Spoil (1980 to 1982)	36
17. Effects of Seeding and Fertilizer Rates on Vigor on Spoil Topdressed with Mineral Soil (1980 to 1982)	37
18. Effects of Seeding and Fertilizer Rates on Seedhead Production on Spoil (1980 to 1982)	38

Table	Page
19. Effects of Seeding and Fertilizer Rates on Seedhead Production on Spoil Topdressed with Mineral Soil (1980 to 1982)	39
20. Effects of Seeding and Fertilizer Rates on Thatch Accumulation (1980)	40
21. Nutrient Levels in Three Fertilizer Treatment Plots (1982) ..	42
22. Plant Nutrient Concentrations in Aerial Biomass as Affected by Fertilizers (1982)	43
23. Nutrient Uptake (kg/ha) in Aerial Biomass as Affected by Fertilizers (1982)	45

ACKNOWLEDGMENTS

The authors wish to express thanks to H. Tomm and Gail Tucker for their help in assessing the trials, and to the Edson Forest, Robb Ranger District, for their assistance and co-operation. Special thanks are extended to J. Carson of the Alberta Soil and Feed Testing Laboratory, Alberta Agriculture, Edmonton, for taking utmost care in carrying out the analyses on the soil and plant materials.

1. INTRODUCTION

The demand for thermal and metallurgical coal in recent times has led to an upsurge in surface mining for this energy resource in the Eastern Slopes and mountain regions of Alberta. This has also meant an increase in the disturbance of land in environments which are sometimes very sensitive and the disruption in the timber resource extraction of the areas. The area is also a critical headwaters region for the Prairie provinces. Some of these lands provide habitat and range for game of all kinds; recreational opportunities including hunting, hiking, trailriding, fishing and wilderness travel; and timber resource. The impact of extractive resource developments on these often fragile areas could be severe as the demand for coal and other uses grows.

Establishing a vegetative ground cover is a common method of controlling erosion and restoring some productivity and it often serves as the first step to reforestation. Unfortunately, little effort was devoted to mined land reclamation research until recently. Few guidelines are firmly established in the use of adaptable plant species and cultural techniques suitable for disturbed land reclamation in the area.

The purposes of the trials discussed in this progress report are to evaluate the:

- (i) adaptability of some selected agronomic grasses and legumes to the mine site environment of this high altitude area,

- (2) effects of seeding and fertilizer rates on the plant cover establishment and growth, and
- (3) effects of topdressing with mineral soil on plant growth.

Russell and Takyi (1979) and Takyi and Russell (1980) reported the results achieved during the first and second year of the experiments. This report provides the summaries of the results for 1980, 1981 and 1982.

2. STUDY AREA

2.1 Location and Physiography

The experiments are located on an abandoned mine which is 1.6 km SE of Cadomin (S1/2 32-46-23-W5M) in the northeastern slopes of the outlying Nikanassin Range of the Rocky Mountains at 1 675 m ASL just below tree line. The site falls within the section of Rowe's Subalpine Forest Region.

Strip mining for coal commenced at this site in 1945 and continued until the mine was abandoned in 1952 (Lake, 1967).

2.2 Climate and Weather

The climate is classified as subarctic cold snow forest (DFC) in Kopen's system of climatic classification (Longley, 1970). A humid microthermal climate with cold winters and short cool summers is characteristic. The area receives a total summer (May-September) precipitation of about 450 mm, with a mean temperature of about 6°C, and has a total of 130 days with mean temperature above -2°C (Powell and MacIver, 1976). The average frost free period in this area is generally fewer than 60 days (Bowser, 1967). Root (1976) reported high winds reduced snow accumulation in winter and increased potential evaporation in summer.

He concluded that soil moisture deficiency and high winds were the major factors inhibiting vegetation establishment and growth on the mine site.

2.3 Site Vegetation

Vegetation on the disturbed sites is very sparse, consisting of isolated plants in open communities. Root (1976) has estimated the total plant cover to be less than 10% in the disturbed areas. In several places the spoil has remained bare since mine abandonment. A total of 112 vascular plant species have been identified on the mine site (Russell - unpublished data).

2.4 Soil and Spoil

Orthic Gray Luvisols, Bisequa Gray Luvisol and Eutric Brunisols are the most common soils in the area. Parent materials of most of these soils consist of weathered products of glacial materials (Dumanski et al. 1972). The site is characterized by extensive flat-topped spoil heaps composed largely of sandstone, siltstone, shale and coal fragments (Russell and Takyi, 1979).

3. MATERIALS AND METHODS

3.1 Establishment of Field Trials

The details of procedures, methods of site preparation, and map of the trial layouts are included in the reports by Russell and Takyi (1979), Takyi and Russell (1980). Only a brief resume is given here.

3.2 Precipitation and Windspeed Measurements

A Taylor Clear-Vu rain gauge and an anemometer (Belford Instrument Co., Model 5-349C) were set up on the mine site on June 23, 1978, for the active growing season of that year and in every subsequent years. A 2.54 cm of mineral oil was added to reduce water evaporation from the gauge. Readings were made at frequent intervals which corresponded closely with visits to the site.

3.3 Agronomic Species Adaptability Trials

Two separate but identical trials were established in June 1978, one on spoil and the other on spoil topdressed with mineral soil. The mineral soil was stripped from a nearby undisturbed area, hauled to the mine site, and spread to an average depth of 20 cm in the fall of 1977.

The trials were designed to test the adaptability of nine agronomic grasses and legumes. A randomized complete block field design was used with four replications. Each plot measured 2.5 m x 6.0 m (1.5×10^{-3} ha).

Uniform seedbeds were prepared by raking each plot before and after broadcasting the seed and fertilizer by hand. All seeds were applied at a rate of 60 kg/ha. The grasses and grass-legume mix were fertilized with 60 kg nitrogen (N)/ha, 30 kg phosphorus (P)/ha, and 62 kg potassium (K)/ha. The legumes received 20 kg N/ha, 30 kg P/ha, and 62 kg K/ha. The sources of fertilizer N were urea (46-0-0) and 10-30-10; P source was 10-30-10; and K sources were 10-30-10 and potassium chloride (0-0-60).

In 1979 (early July), 1980 and 1981 (early June), both the spoil and topdressed plots received maintenance fertilizer. The grasses received 60 kg N/ha as urea, 40 kg P/ha as triple superphosphate, and 60 kg K/ha as potassium chloride. The legumes received only P and K at the same rates and of the same sources as the grasses. All fertilizers were broadcast by hand. In 1982, no maintenance fertilizer was applied.

The species sown were: Kentucky Bluegrass (Poa pratensis "Nugget"), Kentucky Bluegrass (Poa pratensis "Park"), Brome grass (Bromus inermis "Carlton"), Creeping Red Fescue (Festuca rubra "Durlawn"), Crested Wheatgrass (Agropyron desertorum "Nordan"), Timothy (Phleum pratense "Climax"), Alsike Clover (Trifolium hybridum "Aurora"), Alfalfa (Medicago sativa "Rambler") and Sweet Clover (Melilotus officinalis "Yukon"). In addition, a mix of all species in equal proportions by weight was also seeded as one of the treatments.

Legume seeds were dry mixed with appropriate commercial inoculant prior to sowing. The trials were fenced to exclude ungulates and recreational vehicles.

3.4 Agronomic Species Seed-Mix, Seeding Rates and Fertilizer Rates Trials

Two separate but identical trials were established in June 1978, one on spoil and the other on spoil topdressed with 20 cm of mineral soil. The source of the top soil used was the same as for the adaptability trials. A randomized complete block field design was used with three replications. The plots were 2.5 m x 4.0 m (10^{-3} ha) in size.

Uniform seedbeds were prepared by raking each plot before and after broadcasting the seed and fertilizer by hand. The seeding rates were: 30, 60, 90 and 120 kg/ha. The seed mixture was composed of creeping red fescue (40% by weight), white clover (12% by weight), "climax" timothy (24% by weight) and "canon" Canada bluegrass (24% by weight). The mixture was dry mixed with commercial legume (clover) inoculant prior to sowing.

The fertilizer rate treatments on both spoil and topdressed plots were: 40-20-40, 60-30-60, 80-40-80, 80-40-80 (in two equal applications, half on June 21 and half on August 3, 1978), and 0-0-0 (NPK in kg/ha). The sources of fertilizers used were the same as was used for the adaptability trials. During 1979 (early July), 1980 and 1981 (early June), both the spoil and topdressed plots received NPK maintenance

fertilization similar to the treatment fertilization in the year of establishment (1978). The maintenance fertilizer rates during these years on both spoil and topdressed plots were: 40-17-20; 60-26-30; 80-35-40; 80-35-40 (split); and (control), 0-0-0 (NPK in kg/ha). A complete 14-14-7 fertilizer was used. In 1982, application of maintenance fertilizer was discontinued.

3.5 Assessment Methods

3.5.1 Plant Cover

Estimates of percent plant cover were made in early summer by visual estimation and then by using a 0.5 m x 0.5 m quadrat with a grid of 100 subquadrats. One estimate was made by visual estimation and two by the quadrat.

The quadrat was placed in two representative areas in each plot and a count made of the number of sub-quadrats filled and/or partially filled sub-quadrats were subjectively calculated to obtain the percent plant cover estimate. Thus percent plant cover as measured here is defined as the area covered by above-ground living test plant materials as viewed perpendicularly from above in the reference area (quadrat). In each case, independent estimates were made by two individuals. The average of the estimated values obtained for a treatment was used in statistical analyses.

3.5.2 Biomass Production

Biomass samples were collected at the time of plant cover assessment by clipping plant material at 4.0 cm above the ground level within a 0.5 m x 0.5 m quadrat randomly placed in each plot.

The clippings were air dried for two weeks and then placed in a forced air oven at 65°C for 18 hours prior to weighing.

3.5.3 Vigor, Thatch Accumulation and Seedhead Production

Visual estimates of vigor and seedhead production of the species grown on both experiments (1980-82) were carried out by ranking each treatment on a scale of 1 (poor), 2 (poor to fair), 3 (fair), 4 (fair to good), 5 (good), 6 (good to excellent) to 7 (excellent). Similarly, estimation of thatch accumulation by the species for both experiments was made in 1980. Although this rating is subjective in nature, statistical analyses of the results were made to identify broad differences between treatments.

3.5.4 Species Occurrence, Dominant Species, Seed Dominance and Seed

Viability

The relative presence or absence of the species and dominant species was determined for the seed-mix-fertilizer experiment in 1980. In each plot a 0.5 m x 0.5 m quadrat was placed twice to assess the presence or absence of each species seeded in four 0.2 m x 0.2 m (sub-plots) within the quadrat.

In each plot a visual estimate was made on the relative dominance of species established and the relative abundance in seedhead production.

A subjective assessment of adaptability trial was made in 1980 whether or not the species had the apparent self-seeding ability. Seeds produced in this trial in 1981 were collected and tested to determine whether or not the species grown in this environment are capable of producing viable seeds, and, subsequently, self-seeding. Germination, content of pure seed, pure living seed, hard seed and impurities tests were carried out by Agriculture Canada Regional Seed Laboratory in Edmonton.

3.5.5 Physical and Chemical Analyses of Spoil, Soil (Topdress) and Biomass

Physical. Bulk density of the spoil was estimated by field method as described by Lavkulich (1981). Infiltration rates on the spoil and spoil topdressed were estimated by a standard double ring infiltrometer system of the type produced by Eijkelkamp B.V., Productgroup 10 of Letham, the Netherlands; and moisture content (oven dry basis at 105°C) was determined before and after infiltration tests. To avoid drastic disturbances of the relatively-small test plots, estimates of bulk density and infiltration rates, and sampling for moisture content determinations were done on spots without vegetation.

Chemical. Samples from selected treatments at 0-15 cm depth were obtained in late September, 1982, and forwarded to the Alberta Agricultural Soil and Feed Testing Laboratory (ASFTL), Edmonton, for determination of available N, P, K, S, and PH, EC and organic matter.

Plant samples from selected treatments harvested July 11, 1982 were analysed by the ASFTL for N, P, K, Ca, Mg and S. The methods of analyses were those routinely used by this laboratory for agricultural soils and plant materials.

3.5.6. Data Analyses

Data were statistically analysed using ANOVA where appropriate and the differences between treatment means were separated for significance using Duncan's Multiple Range Test.

4. RESULTS AND DISCUSSION

4.1 Spoil and Topdressing Characteristics

Particle size analysis of the spoil reported by Takyi (1980) showed 71 percent of the spoil is composed of coarse fragments greater than 2 mm in diameter of which 50 percent is greater than 7.5 mm; and 66 percent of the fine particle (>2 mm) material is sand, 20 percent is silt and 13 percent is clay.

In early summer 1982, infiltration rates of the spoil (Figure 1) and bulk density were estimated. At the same time, the antecedent and saturated moisture content of the spoil was also determined (Table 1). The estimated bulk density and infiltration rates were found excessively high, and the moisture content low and widely variable at few metres intervals on the site. The estimated bulk density of the spoil was 2.36 g/m³. This high figure is ascribable to large rocks within the samples. Wide variations in moisture content of the spoil are attributed to the degree of mixing of coarse and fine materials in the spoil.

The purposes for topdressing with mineral soil over spoil were to reduce the anticipated excessive permeability of the spoil and to improve moisture and nutrient holding and supplying capacities by providing a matrix of soil material. Selected properties of the mineral soil are described by Russell and Takyi (1979) (see Table 2).

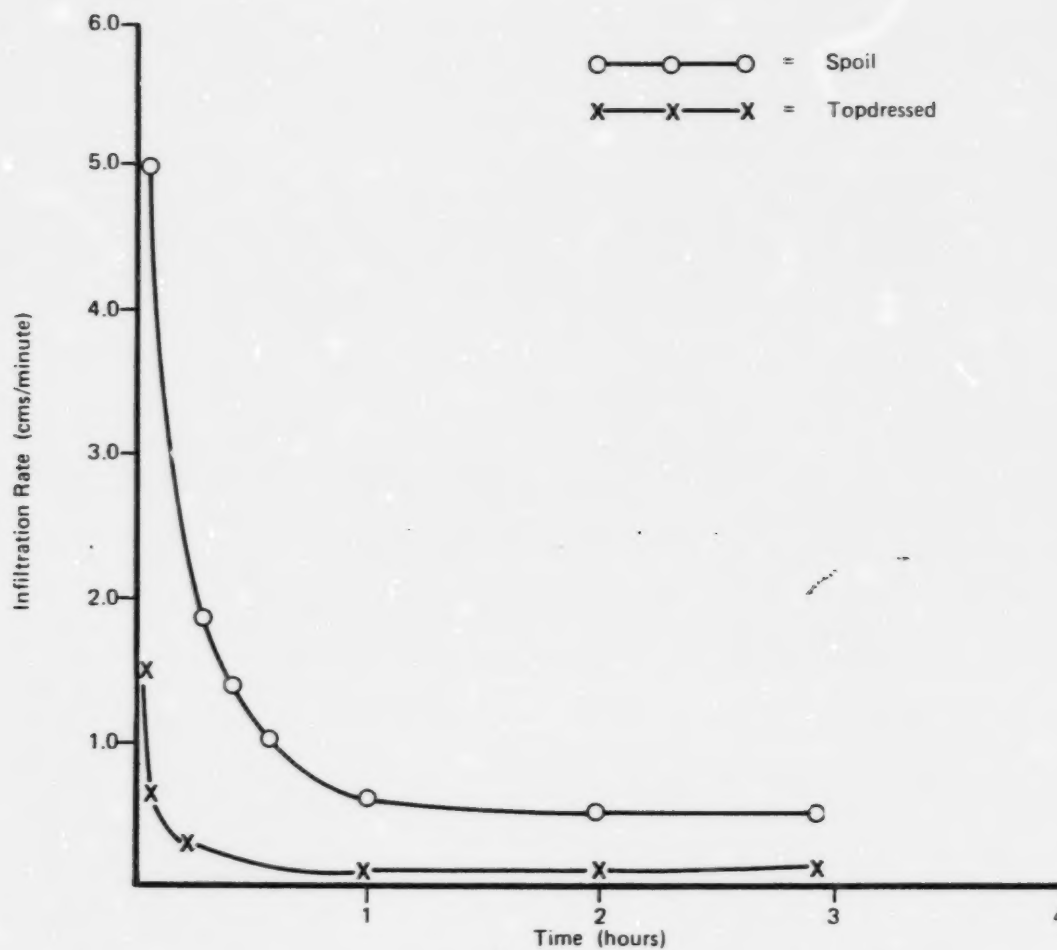


Figure 1. Infiltration Rate on Spoil and Topdressed Plots

Table 1
ANTECEDENT AND SATURATED MOISTURE CONTENT (%)*
OF MATERIALS

Sample Group	Spoil **		Topdressed **	
	Antecedent	Saturated	Antecedent	Saturated
A	6.26	9.54	12.58	13.75
B	8.77	33.71	12.43	16.40
C	7.36	14.73	12.45	15.26
Mean	7.46	19.33	12.49	15.14

*Spoils were sampled from outside test plots without plant cover.
Topdressed were sampled from test plots without plant cover.

**Wide variations in moisture content of the spoils are attributed to the degree of mixing of coarse and fine materials in the spoil. A relatively-large proportion of the sample B is composed of finer soil material and coal fragments than samples A and C.

Table 2
SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE SPOIL AND MINERAL SOIL
(USED AS A TOPDRESSING, RUSSEL AND TAKYI, 1978)

Soil Properties ¹	Spoil	Mineral Soil (Topdressing)
pH (1:2, soil:water)	8.8 ^a	6.8 ^a
Electrical Conductivity (mmhos/cm)	0.2	0.1
Available Plant Nutrients (ppm):		
NH ₄ ⁺ -N	4.1	4.5
NO ₃ ⁻ -N	0.0	0.0
P	0.0	13.0
K	373.0	10.0
Total N (%)	0.15	214.0
Exchangeable Cations (m.e./100g):		0.07
Ca	7.50	8.75
Mg	3.50	2.10
Na	0.70	0.35
K	0.70	0.35
Total Exchange Capacity (m.e./100g)	6.80	11.35
Particle Size (<2 mm)		13.20
% Sand	81.2	56.4
% Silt	10.8	27.6
% Clay	8.0	16.0

¹All analyses were conducted on material less than 2 mm in size

^aadaptability trials

^bfertilizer X seed mix trials

According to Takyi (1980 and 1981), both the mineral soil and spoil are non-saline, have adequate levels of available K and S, but are very low in available N. Levels of available P are very low in the spoil and low to medium in the mineral soil. The CEC (cation exchange capacity) is very low in the spoil and low in the soil. The spoil is strongly alkaline, the mineral soil is near neutral in reaction.

The major differences between the mineral soil and the spoil are in their physical properties. The spoil is primarily a mixture of rock and coal fragments with very little soil-size material. The mineral soil is lower in rock and coarse fragments and higher in finer material. The spoil has comparatively a lower CEC and, therefore, is expected to be lower in nutrient retention ability than the soil, and be more susceptible to loss of added nutrients by leaching.

Results of the soil analyses indicate that the mineral soil is only a slightly more favorable medium than the spoil for plant growth. The mineral soil, however, has been observed to be more susceptible to erosion, and is subject to surface crusting in the plots.

4.2 Precipitation

Precipitation, windspeed and length of growing season are important environmental factors that affect revegetation at high elevation (Johnston et al. 1975). The amounts of precipitation during the growing season as recorded in rain gauge at the experimental site are presented in Table 3. In 1980 and 1981, the total amount of precipita-

tion from July to September were 371 mm and 296 mm respectively. In 1979, from June to August, it was 183 mm (Takyi, 1980). In 1978, during almost the same months, the total precipitation was 294 mm.

Russel and Takyi (1979) have compared the long term trend of precipitation recorded in the Grave Flats and Yellowhead forestry lookout towers, the closest station, with the Cadomin experimental site. In view of their analysis, the 1981 growing season in Cadomin was wet, the 1980 and 1978 were more or less close to long term averages for the area, and the 1979 was relatively dry. The amount of precipitation for the period June to July 1982, was 108 mm averaging 2.3 mm/day which is higher than 1979 average of 1.9 mm/day (Table 3). It is, therefore, inferred that summer precipitation was not a limiting factor for the growth of plant species tested in 1982.

4.3 Snow Cover and Prevailing Winds

According to Takyi and Russell (1980), approximately 80 percent of the area of experiments had no snow cover at the time of their several visits in winters. In the remaining 20 percent, snow cover was patchy and did not exceed 7.0 cm in depth. They cautioned that the poor snow cover and the partial exposure of the rooting system and the plant cover coupled with the strong westerly winter winds can increase the danger of winter-kill of poorly-adapted species.

In 1981 the average wind speed at the site as recorded in the anemometer was about 12 km/h. Wind speeds for Edson (1960-72), 86 km NE from the site for the months of June, July, August and September were

Table 3
PRECIPITATION DURING GROWING SEASONS AT THE EXPERIMENTAL SITE

Year	Period	No. of Days	Total Precipitation in mm	Average Precipitation/Day in mm
1978	June 23 to Sept. 09	78	294.0	3.8
1979	June 07 to Sept. 17	102	198.8	1.9
1980	June 19 to Sept. 12	85	295.6	3.5
1981	June 09 to Sept. 11	94	371.0	3.9
1982	June 15 to July 30*	46	108.2	2.3

*Data to September were not available (rain gauge damaged)

10.9, 19.3, 9.6, and 10.5 km/h respectively averaging 10.3 km/h. Takyi (1981) in 1980 recorded an average wind speed of approximately 10 km/h from July through September at the site. He, however, suspected that the average calculation may be low due to some of the winds registered being missed because of the long intervals between readings. Experience in open spaces in the experimental sites shows that high and gusty winds are frequent and occur throughout the year. The high winds quickly dry soil in the open in summer and blow snow into drifts in depressions in winter. Such strong winds expose plant cover and roots, and make them susceptible to abrasive and frost damages, winter-kill and desiccation in the plots. This situation is further accentuated during the winter when warm chinook winds move and melt the snow. Winds sweeping across this abandoned mine site also dislodge fine particles resulting in surface material drifting. Our observations showed fine soil and spoil particles from plots, especially those with poor or no vegetation, were so transported. Plots with such denuded finer residual surface materials are considered to be poor in water and plant nutrient-holding capacities. These, perhaps, are some of the several causes for the failure of the abandoned mine to achieve complete revegetation more than 26 years after its abandonment, and also explain some of the reasons for difficulty in artificial revegetation in some of the plots.

4.4 Species Adaptability Trials

Considerable differences were found in percent plant cover, biomass production, seedhead production and plant vigor (Tables 4-7)

between species on spoil and topdressed plots during 1980, 1981 and 1982 (see also Takyi and Russell, 1980 and Russell and Takyi, 1979). With most species plant cover increased or remained high through to the end of the fourth growing season (1981) during which maintenance fertilization was carried out (Table 4). Plant cover dropped considerably for most species in the fifth growing season (1982) when maintenance fertilization was stopped. Very high reduction in plant cover took place with alsike clover and the sweet clover thinned out considerably. The reduction of the two legumes is perhaps attributable to the exposed windy conditions in the winter at this mine site and not to the withdrawal of fertilizers in the fifth growing season. Cover remained high with alfalfa and the mixed species even after fertilizer withdrawal. With the seed-mix the continued good plant cover is ascribed mostly to alfalfa which apparently continued to fix nitrogen to enable it to maintain good growth. A few alfalfa plants were uprooted and examined for nodules. The high modulation indicated that the alfalfa was perhaps actively fixing nitrogen. The same was true of the sweet clover which still remained.

Biomass yields were measured in 1979 (Takyi and Russell, 1980) and again in 1981 (Table 5). In each species, production increased considerably between 1979 (Takyi and Russell, 1980) and 1981 growing seasons - during the maintenance fertilization. Production differences between species are attributable to the growth habits of each species. The legumes and the large seeded grasses which generally produce large plants gave the highest biomass yield. Generally species with good plant

Table 4

PERCENT PLANT COVER FROM 1980-1982¹

Species	Spoil		Topdressed	
	1980	1981	1980	1981
Kentucky Bluegrass-Nugget	22.1abcdef ²	59.0a	23.9a	68.8a
Kentucky Bluegrass-Park	23.5abcdef	78.2abc	54.4d	87.2cde
Bromegrass	34.0cdef	93.4c	27.9ab	98.0e
Creeping Red Fescue	32.2bcdef	81.8abc	39.6abcd	93.5de
Crested wheatgrass	25.9abcdef	69.2abc	30.9ab	81.8abcd
Timothy	38.8def	75.3abc	44.0bcd	91.3cde
Alsike clover	26.6abcdef	89.5c	28.1ab	91.3cde
Alfalfa	40.0ef	96.0c	52.1cd	99.2e
Sweet clover	6.9a	71.4abc	21.8a	76.0ab
Species mix (all above)	45.1f	93.0c	40.6abcd	99.0e

¹The last maintenance fertilizer was carried out in 1981.

²Means followed by a common letter in a given year on a given medium are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of four.

Table 5
AERIAL BIOMASS PRODUCTION¹ IN 1981

Species	Spoil	Topdressed
Kentucky Bluegrass-Nugget	30.4a ²	19.3a
Kentucky Bluegrass-Park	44.9ab	44.3ab
Bromegrass	105.6abc	145.1de
Creeping Red Fescue	65.4ab	66.7abc
Crested wheatgrass	87.1abc	110.8cde
Timothy	46.9ab	83.7bcd
Alsike clover	115.1bc	124.8cde
Alfalfa	201.5d	171.0e
Sweet clover	149.8cd	138.3de
Species mix (all above)	113.6abc	159.3e

¹gm/0.25 m²

²Means for a given medium followed by a common letter are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean values based on a sample size of four.

cover also gave good yields and seedhead productions (Table 6). With most species production was better on topdressed plots than on the spoil plots.

In addition to decrease in plant cover (Table 4), a deterioration in vigor occurred (Table 7), especially of the grasses, as manifested by chlorosis and some mortality in 1982 as maintenance fertilization was discontinued.

Analyses of spoil and topdressed plots for four species (Table 8) showed low levels of available N in both growth media. Phosphorus level was slightly better and rated low to medium. The deficiency of N in the growth medium is considered to have caused the decline in vegetative yields and vigor of grasses in 1982. Potassium and S supplies were adequate in both growth media. In general, topdressed medium offered a slightly better edge in available nutrient reserve than the spoil. This resulted in better production with topdressing. Some N was possibly lost through leaching and very little of it was retained in the media.

Alfalfa as well as the seed-mix which included alfalfa were the best not only in cover and biomass but also in vigor of vegetal production in 1982. The presence of alfalfa in the seed-mix is credited for the continued good growth of the mixture after maintenance fertilization stoppage at the end of the fourth year.

A rating of thatch accumulation (Table 9) in 1980 showed the species that ranked high in percent cover, biomass and seedhead productions also accumulated the most thatch which reduced surface runoff and erosion. The seed germination test result (Table 10) shows that alfalfa,

Table 6
SEEDHEAD PRODUCTION*

Species	Spoil			Topdressed		
	1980	1981	1982	1980	1981	1982
Kentucky Bluegrass-Nugget	4.0ab ¹	5.0abc	4.0cde	5.5bc	4.5a	4.2abcde
Kentucky Bluegrass-Park	2.8ab	5.0abc	3.5de	1.8a	5.0ab	1.2g
Bromegrass	3.2ab	5.8bcd	6.7ab	4.0abc	6.3cd	4.7abc
Creeping Red Fescue	5.5b	5.8bcd	3.5de	4.8abc	6.3cd	3.5abcdef
Crested wheatgrass	1.2a	4.3ab	5.7bc	1.5a	5.5abc	4.5abcd
Timothy	1.8a	3.8a	4.0cde	4.0abc	6.0bcd	4.2abcde
Alsike clover	4.1ab	5.5bcd	1.2	6.2c	7.0d	2.5cdefg
Alfalfa	3.5ab	7.0d	6.7ab	4.5abc	7.0d	5.2ab
Sweet clover	1.4a	6.5cd	7.0a	2.8ab	7.0d	1.7bcdef
Species mix (all above)	1.5a	7.0d	5.2bcd	3.2abc	7.0d	5.5a

*Subjective rating based on a scale of one (poor) to seven (excellent). Fertilizer last applied in 1981.
¹Means followed by a common letter in a given year on a given medium are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of four.

Table 7
PLANT VIGOR*

Species	Spoil			Topdressed		
	1980	1981	1982	1980	1981	1982
Kentucky Bluegrass-Nugget	7.0b	4.8bcd	1.5cd	7.0c	5.5ab	3.0cde
Kentucky Bluegrass-Park	4.8ab	4.0ab	1.5cd	3.0a	5.5ab	2.0e
Bromegrass	4.8ab	5.5bcde	4.5	3.8ab	6.5bc	6.0ab
Creeping Red Fescue	7.0b	5.0bcd	2.7b	7.0c	6.5bc	5.0abc
Crested wheatgrass	4.5ab	4.3abc	2.2bc	4.0ab	5.5ab	3.2cde
Timothy	5.5ab	2.8	1.5cd	4.5b	5.0a	3.0cde
Alsike clover	4.4a	5.5bcde	1.2d	7.0c	7.0c	2.7de
Alfalfa	6.5ab	7.0e	7.0	6.5c	7.0c	6.2a
Sweet clover	6.1ab	6.5de	6.2a	7.0c	7.0c	4.5abcd
Species mix (all above)	5.5ab	6.0cde	5.5a	6.5c	7.0c	6.2a

*Subjective rating based on a scale of one (poor) to seven (excellent). Fertilizer last applied in 1981. Means followed by a common letter in a given year on a given medium are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of four.

Table 8
NUTRIENT LEVELS IN FOUR SELECTED SPECIES TREATMENT PLOTS
(1982)

	NH ₄ ⁺ -N	NO ₃ ⁻ -N	P	K	S (ppm)	PH (H ₂ O)	EC (mmhos/cm)
	----- Kg/ha -----						
<u>SPOIL</u>							
Bromegrass	5.7	0.0	19.0	334.6	5.1	7.7	0.3
Creeping red fescue	6.2	0.0	31.3	194.5	4.8	7.9	0.3
Alfalfa	7.6	1.4	33.6	212.8	6.0	7.8	0.3
All species - mix	6.8	0.0	32.5	214.5	5.7	7.8	0.3
<u>TOPDRESSED</u>							
Bromegrass	7.3	0.0	31.3	254.6	4.8	6.0	0.2
Creeping red fescue	7.3	0.0	35.8	291.0	5.2	6.1	0.2
Alfalfa	7.0	1.1	29.1	227.0	3.5	6.4	0.2
All species - mix	7.0	0.0	53.7	261.5	3.7	6.1	0.2

Table 9
THATCH ACCUMULATION* (1980)

Species	Spoil	Topdressed
Kentucky Bluegrass-Nugget	1.0c ¹	1.0d
Kentucky Bluegrass-Park	2.0c	2.5ab
Bromegrass	2.2bc	2.5ab
Creeping red fescue	1.0c	1.0d
Crested wheatgrass	2.0c	2.2abc
Timothy	1.5c	3.0a
Alsike clover	0.6c	1.0d
Alfalfa	1.2c	1.2cd
Sweet clover	4.0ab	1.2cd
Species mix (All above)	4.0ab	2.0abcd

*Rating on a scale of poor (1), fair (2), good (3) and excellent (4).

¹Means followed by a common letter are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean values based on a sample size of four.

Table 10

PERCENT GERMINATION OF SEED IN OCTOBER, 1981*

Species	Spoil	Topdressed
Kentucky Bluegrass-Nugget	79.5	87.2
Bromegrass	33.0	57.0
Creeping Red Fescue	87.0	79.5
Crested wheatgrass	55.5	67.5
Timothy	83.0	75.0
Alsike clover	98.0	93.0
Alfalfa	71.0	36.0
Sweet clover	90.0	94.0

*Seeds were manually cleaned to get rid of foreign materials, unfilled seeds, etc. prior to sending to the laboratory. Sample tested for germination only which included hard seeds.

bromegrass and creeping red fescue which have performed well on the site since establishment also produced good percentage of seed for germination, and presumably have greater selfseeding ability in this environment when grown on topdressed spoil than on spoil.

4.5 Seeding Rates and Fertilizer Rates Trials

The results for the period from 1980 through 1982 are summarized in Tables 11 through 18. Significant changes occurred in percent plant cover, biomass yields, seedhead production and plant vigor on spoil and topdressed spoil during the three-year period. The unfertilized spoil produced practically no plant cover or biomass. On the other hand, the unfertilized topdressed spoil supported some growth and subsequent production of cover and biomass but the yield was too meager and the vigor was poor.

The application of fertilizer resulted in a significant increase in percent plant cover (Tables 11 and 12) and biomass production (Tables 13 and 14) on both spoil and topdressed plots. Of the four species grown in the seeded mix only the three grasses persisted in the sward (Table 15) and maintained the high cover and biomass productions all through to 1981 during which annual fertilization was maintained. White clover had essentially disappeared from both spoil and topdressed plots with or without fertilizer since the end of the third (1980) growing season. It is considered that white clover is either not well adaptable to this high elevation, exposed site environment or did not compete well on these

Table 11

EFFECTS OF SEEDING AND FERTILIZER RATES ON PERCENT PLANT
COVER ON SPOIL (1980 TO 1982)

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80*	
1982						
30	2.2	40.5	61.2	57.5	60.5	44.4a ¹
60	1.1	44.1	60.5	77.6	81.0	52.9a
90	2.0	49.1	78.2	68.1	78.9	55.3a
120	3.5	40.5	67.3	81.1	81.9	54.9a
Mean (fertilizer rate)	2.2 ¹	43.5	66.8a	71.1a	75.6a	
1981						
30	0.8	67.1	83.7	86.2	94.3	66.4a
60	0.7	67.1	82.5	96.2	97.7	68.8a
90	1.1	76.0	93.3	92.4	97.4	72.0a
120	2.4	81.7	90.7	97.3	96.3	73.7a
Mean (fertilizer rate)	1.3	73.0	87.6a	93.0a	96.4a	
1980						
30	0.8	40.7	66.7	65.8	65.3	47.9a
60	1.3	42.2	54.4	80.9	93.5	54.5a
90	1.4	45.7	76.4	77.7	86.8	57.6a
120	3.1	51.4	69.9	82.3	82.7	57.9a
Mean (fertilizer rate)	1.6	45.0	66.8a	76.7a	82.1a	

*Split applied.

¹Means followed by a common letter for a given year are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

Table 12

**EFFECTS OF SEEDING AND FERTILIZER RATES ON PERCENT PLANT COVER
ON SPOIL TOPDRESSED WITH MINERAL SOIL (1980 to 1982)**

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80*	
1982						
30	5.6	40.5	67.0	71.6	76.9	52.3a ²
60	9.1	53.6	62.2	81.1	82.1	57.6a
90	9.4	46.9	70.0	81.2	74.3	56.4a
120	7.4	50.1	67.7	80.7	88.2	58.8a
Mean (fertilizer rate)	7.9 ¹	47.8	66.7a	78.6a	80.4a	
1981						
30	8.9	77.2	91.2	93.3	97.7	73.7a
60	18.4	77.4	94.1	96.6	96.3	76.6a
90	20.9	83.7	90.2	96.2	98.7	77.9a
120	16.8	84.5	92.4	98.0	98.4	78.0a
Mean (fertilizer rate)	16.3	80.7	92.0a	96.0a	97.8a	
1980						
30	2.9	59.5	79.0	78.8	95.1	63.1a
60	8.2	68.1	91.5	87.7	90.4	69.2a
90	10.8	75.7	83.7	85.4	87.7	68.7a
120	7.0	70.9	76.0	93.8	87.3	67.1a
Mean (fertilizer rate)	7.4	68.5	82.6a	86.4a	90.1a	

*Split applied.

¹Means followed by a common letter for a given year are not significantly different at the five percent level (Duncan's Multiple Range Test).

Table 13

EFFECTS OF SEEDING AND FERTILIZER RATES ON
BIOMASS PRODUCTION (gm/0.25m²) ON SPOIL

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80*	
1982						
30	1.4	41.4	84.0	36.6	83.5	49.4a ¹
60	0.4	47.1	69.8	35.2	78.6	46.2a
90	2.5	43.2	76.2	68.3	54.7	49.0
120	4.1	38.7	64.1	80.7	81.3	53.8a
Mean (fertilizer rate)	2.1 ¹	42.6a	73.5a	55.2a	74.5a	
1981						
30	0.0	84.8	132.4	158.2	108.1	96.7a
60	0.0	80.3	65.9	118.5	137.9	80.5a
90	0.0	90.2	122.2	127.7	97.5	87.5a
120	0.0	70.5	137.2	142.0	138.0	97.5a
Mean (fertilizer rate)	0.0	81.5b	114.4ab	136.6a	120.4ab	
1980						
30	0.1	42.1	68.7	114.7	98.5	64.8a
60	0.0	57.3	55.9	90.5	111.9	63.1a
90	0.3	39.3	78.3	100.2	98.2	63.3a
120	0.2	46.6	76.3	92.8	109.1	65.0a
Mean (fertilizer rate)	0.1	46.3b	69.8ab	99.5a	104.4a	

*Split applied.

¹Means followed by a common letter for a given year are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

Table 14

EFFECTS OF SEEDING AND FERTILIZER RATES ON BIOMASS PRODUCTION
(gm/0.25m²) ON SPOIL TOPDRESSED WITH MINERAL SOIL

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80*	
1982						
30	2.3	67.4	80.0	116.7	84.0	70.1a ¹
60	3.4	61.0	78.6	85.6	102.5	66.2a
90	9.2	54.9	103.1	102.7	106.9	75.4a
120	7.3	68.0	86.2	98.4	83.2	68.6a
Mean (fertilizer rate)	5.5 ¹	62.8a	87.0a	100.8a	94.1a	
1981						
30	4.8	103.6	152.4	153.4	156.4	114.1a
60	9.6	105.5	150.8	172.6	152.5	118.2a
90	10.9	90.5	140.0	132.8	188.4	112.5a
120	7.3	122.9	149.8	160.3	180.5	124.2a
Mean (fertilizer rate)	8.2	105.6bc	148.3abc	154.8ab	169.5a	
1980						
30	0.9	39.5	77.7	105.5	166.5	78.0a
60	4.4	51.5	94.3	146.8	135.8	86.6a
90	4.6	57.1	91.3	103.4	121.2	75.5a
120	3.7	55.1	73.1	139.5	127.8	79.8a
Mean (fertilizer rate)	3.4	50.8c	84.1bc	123.8ab	137.8a	

*Split applied.

¹Means followed by a common letter for a given year are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

Table 15

EFFECTS OF FERTILIZER RATES ON SEEDHEAD PRODUCTION*

Growth Media	Species	Year	0-0-0**	40-20-40	60-30-60**	80-40-80**	80-40-80***
Spoil	Timothy	1980	0.0a ¹	3.0b	3.7b	5.8c	6.0c
	Fescue		0.0a	2.2b	2.8b	2.8b	3.0b
	Bluegrass		0.0a	2.1b	2.9bc	2.5b	4.2c
	White clover		0.0a	0.1a	0.0a	0.0a	0.0a
	(1980 Mean		0.0	1.9	2.4	2.8	3.3)
Topdressed	All species	1981	2.4a	5.4b	6.6b	6.7b	6.4b
		1982	1.0c	2.1bc	3.1ab	3.8a	4.7a
		(Mean	1.1	3.1	4.0	4.4	4.8) = 3.5
	Timothy	1980	1.2a	3.0b	4.5c	4.8cd	5.8d
	Fescue		1.2a	3.0b	3.3b	3.0b	3.6b
	Bluegrass		0.7a	3.3b	4.3bc	5.0cd	5.8d
	White clover		0.5a	0.7a	0.0a	0.0a	0.0a
	(1980 Mean		0.9	2.5	3.0	3.2	3.8)
	All species	1981	3.2a	5.5b	6.6c	6.7c	6.7c
		1982	1.2c	2.2bc	3.4ab	4.1a	4.3a
		(Mean	1.8	3.4	4.3	4.6	4.9) = 3.8

¹Means for a given species in a given year followed by a common letter are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

*Subjective rating based on a scale of one (poor) to seven (excellent).

**N-P-K (kg/ha)

***Split applied.

growth media. Maximum plant cover (98%) and biomass were obtained in 1981 with the highest rate of fertilizer on topdressed plots. Similar trend was observed with plant vigor (Tables 16 and 17) and seedhead production (Tables 18 and 19) estimated in 1980, 1981 and 1982, and thatch accumulation (Table 20) estimated during 1980 growing season.

It was noted that although there was a trend for increased ground cover or dry matter yields by split application over a single application of 80-40-80 fertilizer, the difference was not significant statistically.

The relative presence or absence of the four species seeded in 1978 and determined in 1980 showed timothy, creeping red fescue and Canada blue-grass occurred in all fertilized spoil, fertilized topdressed spoil and unfertilized topdressed spoil plots, and they were the dominant species in the sward in order of their relative presence. No species was present on unfertilized spoil plots. White clover practically did not exist in either of the growth mediums.

Seeding rates, ranging from 30 to 120 kg/ha, did not have any significant effects on plant cover, biomass production, seedhead production, vigor, thatch accumulation and relative presence or absence of the species on spoil and topdressed spoil plots. Sixty kg/ha seemed to be the optimum seeding rate.

Application of maintenance fertilizer was stopped starting in 1982. As a result, plant cover, biomass and seedhead productions, as well as vigor, declined substantially in comparison with previous years during which maintenance fertilization was carried out. Incidences of

Table 16
EFFECTS OF SEEDING AND FERTILIZER RATES ON VIGOR*
ON SPOIL (1980 to 1982)

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80**	
1982						
30	1.0	2.0	3.3	3.7	4.3	2.9a ¹
60	1.0	2.7	2.3	4.3	5.0	3.1a
90	1.0	1.7	3.7	3.0	4.7	2.8a
120	1.0	2.0	3.3	4.3	4.7	3.1a
Mean (fertilizer rate)	1.0 ¹	2.1c	3.1bc	3.8ab	4.7a	
1981						
30	2.7	5.7	6.7	7.0	7.0	5.8a
60	1.0	5.3	6.0	7.0	7.0	5.3b
90	2.7	4.7	6.3	6.0	7.0	5.3b
120	2.3	4.3	6.0	6.7	7.0	5.3b
Mean (fertilizer rate)	2.2a	5.0b	6.3bc	6.7c	7.0c	
1980						
30	1.0	2.7	4.3	5.7	6.0	3.9a
60	1.7	3.3	4.0	5.3	7.0	4.3a
90	1.3	3.7	4.3	5.3	6.7	4.3a
120	1.0	3.7	4.0	5.7	5.3	3.9a
Mean (fertilizer rate)	1.2a	3.3b	4.1c	5.5d	6.2e	

*Subjective rating based on a scale of one (poor) to seven (excellent).

**Split applied.

¹Means followed by a common letter for a given year are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

Table 17

EFFECTS OF SEEDING AND FERTILIZER RATES ON VIGOR* ON SPOIL
TOPDRESSED WITH MINERAL SOIL (1980 to 1982)

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80**	
1982						
30	1.0	2.7	3.7	3.7	3.7	3.0a ¹
60	1.0	2.3	3.7	4.3	4.3	3.1a
90	1.0	2.0	3.3	4.0	4.7	3.0a
120	1.7	2.0	3.0	4.3	4.7	3.1a
Mean (fertilizer rate)	1.2c ¹	2.2bc	3.4ab	4.1a	4.3a	
1981						
30	2.7	5.3	6.7	7.0	7.0	5.7a
60	3.0	5.0	6.7	7.0	7.0	5.7a
90	3.0	4.7	6.7	7.0	7.0	5.7a
120	3.0	5.0	6.7	7.0	7.0	5.7a
Mean (fertilizer rate)	2.9a	5.0b	6.7c	7.0c	7.0c	
1980						
30	1.0	3.0	4.0	5.3	6.7	4.0a
60	1.0	3.3	5.0	5.3	6.0	4.1a
90	1.0	3.0	4.0	5.0	6.0	3.8a
120	1.0	3.7	4.0	5.7	6.3	4.1a
Mean (fertilizer rate)	1.0a	3.2b	4.2c	5.2d	6.2e	

*Subjective rating based on a scale of one (poor) to seven (excellent).

**Split applied

¹Means followed by a common letter for a given year are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

Table 18
EFFECTS OF SEEDING AND FERTILIZER RATES ON SEEDHEAD
PRODUCTION* ON SPOIL (1980 to 1982)

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80**	
1982						
30	1.0	2.0	3.3	3.7	4.3	2.9a ¹
60	1.0	2.7	2.3	4.3	5.0	3.1a
90	1.0	1.7	3.7	3.0	4.7	2.8a
120	1.0	2.0	3.3	4.3	4.7	3.1a
Mean (fertilizer rate)	1.0c ¹	2.1bc	3.1ab	3.8a	4.7a	
1981						
30	2.7	6.3	7.0	7.0	7.0	6.0a
60	1.0	5.3	6.7	7.0	6.3	5.3a
90	3.0	5.3	6.7	6.7	6.0	5.5a
120	3.0	4.7	6.0	6.3	6.3	5.3a
Mean (fertilizer rate)	2.4a	5.4b	6.6b	6.7b	6.4b	
1980						
30	0.0	1.9	3.7	3.6	4.1	2.7a
60	0.0	2.5	3.4	2.8	4.0	2.5a
90	0.0	2.0	2.7	3.3	3.1	2.2a
120	0.0	2.2	3.0	3.4	3.1	2.3a
Mean (fertilizer rate)	0.0b ¹	2.1a	3.2a	3.3a	3.6a	

*Subjective rating based on a scale of one (poor) to seven (excellent).

**Split applied

¹Means followed by a common letter in a given year are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

Table 19

**EFFECTS OF SEEDING AND FERTILIZER RATES ON SEEDHEAD PRODUCTION*
ON SPOIL TOPDRESSED WITH MINERAL SOIL (1980 to 1982)**

Seeding Rate (kg/ha)	N-P-K (kg/ha)					Seeding Rate Mean
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80**	
1982						
30	1.0	2.7	3.7	3.7	3.7	3.0a ¹
60	1.0	2.3	3.7	4.3	4.3	3.1a
90	1.0	2.0	3.3	4.0	4.7	3.0a
120	1.7	2.0	3.0	4.3	4.7	3.1a
Mean (fertilizer rate)	1.2c ¹	2.2bc	3.4ab	4.1a	4.3a	
1981						
30	2.7	5.7	7.0	6.7	6.7	5.8a
60	3.7	6.0	6.3	6.7	6.3	5.8a
90	3.3	5.0	7.0	6.3	7.0	5.7a
120	3.3	5.3	6.3	7.0	6.7	5.7a
Mean (fertilizer rate)	3.2a ¹	5.5b	6.6c	6.7c	6.7c	
1980						
30	0.9	2.9	3.6	3.2	4.0	2.9a
60	0.8	3.1	3.2	3.3	3.6	2.8a
90	0.8	1.4	3.1	3.7	3.1	2.4a
120	0.8	1.8	3.2	3.1	3.6	2.5a
Mean (fertilizer rate)	0.8c ¹	2.3b	3.3a	3.3a	3.6a	

*Subjective rating based on a scale of one (poor) to seven (excellent).

**Split applied

¹Means followed by a common letter in a given year are not significantly different at the five percent level (Duncan's Multiple Range Test). mean value based on a sample size of three.

Table 20

EFFECTS OF FERTILIZER AND SEEDING RATES ON THATCH* ACCUMULATION (1980)

Seeding Rate (kg/ha)	N-P-K (kg/ha)										Mean (Seeding Rate)	
	Spoil					Topdressed					Spoil	Topdressed
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80**	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80**		
30	1.0	3.7	3.3	4.3	4.0	1.0	2.7	3.7	4.7	5.7	3.3a ¹	3.6a ¹
60	1.0	2.7	4.3	4.3	4.3	1.0	3.7	4.3	4.7	4.3	3.3a	3.6a
90	1.0	1.7	4.0	4.7	4.0	1.0	2.3	3.3	3.7	5.0	3.1a	3.1a
120	1.0	3.0	4.0	4.7	5.0	1.7	2.7	3.3	4.3	5.7	3.5a	3.5a
Mean (Fertilizer Rate)	1.0a ¹	2.8b	3.9c	4.5c	4.3c	1.2a ¹	2.8b	3.6c	4.3d	5.2e		

¹Means for a given medium followed by a common letter are not significantly different at the five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

*Subjective rating based on a scale of one (poor) to seven (excellent).

**Split applied.

chlorosis of the grasses were conspicuous. The reduction in quantity and vigor of vegetal production was less with topdressed than spoil. Analyses of spoil and topdressed plots (Table 21) identified were low N and P levels, and marginal K levels in all treatments. N, P and K values were slightly higher in the topdressed than the spoil.

A comparison of 1982 available N, P, K and S content of the media with those of the 1978 (baseline) material (Table 2) shows similar level of nutrients, specifically deficiency of N and P. Some loss of N through leaching may have occurred due to the high infiltration rates of the materials. Consequently, there was very little residual available N in the growth media to meet the need of 1982 vegetation. Discontinuation of maintenance fertilization during 1982, therefore, resulted in deficiency of N and P, which caused the decline in yield and vigor of vegetative cover.

Results of plant tissue analyses for 1982, the year fertilization was stopped (Table 22), indicate a general trend of slightly-higher concentration of N, P, K, Ca and Mg with increase in rate of fertilizer applied in the past years. The plants on the topdressed plots show relatively-higher concentrations of nutrients than the spoil. However, the concentrations of these elements are generally low and rank below the average level of Alberta forage crops (Alberta Agriculture, 1977).

Takyi and Leitch (1981) reported high concentrations of N, P and K in aerial biomass of young plant cover in the year of establishment under fertilization in this abandoned mine spoil. The residual effects of fertilizer N, P and K were measured in 1982, after maintenance

Table 21
NUTRIENT LEVELS IN THREE FERTILIZER
TREATMENT PLOTS* (1982)

	NH ₄ ⁺ -N	NO ₃ ⁻ -N	P	K	S (ppm)	PH (H ₂ O)	EC (mmhos/cm)
	----- Kg/ha -----						
<u>SPOIL</u>							
40-20-40**	6.2	0.0	1.7	168.0	5.7	7.9	0.3
80-40-80	6.7	0.0	21.8	107.0	6.4	7.9	0.3
0-0-0	6.0	0.0	0.5	92.4	4.9	8.0	0.3
<u>TOPDRESSED</u>							
40-20-40	8.9	0.0	8.4	139.5	5.8	7.8	0.3
80-40-80	8.9	0.0	23.5	156.5	7.8	6.8	0.3
0-0-0	9.4	0.0	8.4	143.5	6.3	6.9	0.3

*Seeding Rate 60 kg/ha

**N-P-K (kg/ha)

Table 22

PLANT NUTRIENT CONCENTRATIONS IN AERIAL BIOMASS
AS AFFECTED BY FERTILIZERS* (1982)

N-P-K (kg/ha)	SPOIL						TOPDRESSED					
	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
40-20-40	0.48	0.06	0.53	0.32	0.10	0.07	0.60	0.08	0.63	0.27	0.08	0.06
60-30-60	0.72	0.09	0.83	0.39	0.10	0.07	0.74	0.11	0.85	0.28	0.09	0.07
80-40-80	0.85	0.11	0.85	0.41	0.12	0.07	0.94	0.14	1.29	0.35	0.12	0.07
80-40-80**	0.96	0.12	0.88	0.42	0.13	0.07	0.80	0.15	0.96	0.31	0.10	0.07
0-0-0	a	a	a	a	a	a	0.75	0.17	1.18	0.30	0.12	0.14
Average for Alberta grass ^b							1.28	0.15	1.90	0.43	0.18	0.18

*Seeding rate: 60 kg/ha

**Split applied

^aSample area yield too low for analyses.

^bAlberta Agriculture, 1977

fertilization ceased (Table 23). The data indicate that nutrient concentrations were considerably lower after fertilizer withdrawal, and uptake was relatively higher in topdressed fertilized spoil than the fertilized spoil treatments. In other words, the nutrient uptake was higher in treatments which produced better biomass and the growth of vegetation was uniformly distributed in the plots. In 80-40-80 (single) fertilizer application rate in spoil, the growth was patchy. This influenced plant sampling which resulted in lower biomass and thereby the lower nutrient uptake than 60-30-60 and 80-40-80 (split) fertilizer applications.

Table 23

NUTRIENT UPTAKE (kg/ha) IN AERIAL BIOMASS AS AFFECTED
BY FERTILIZERS* (1982)

N-P-K (kg/ha)	SPOIL			TOPDRESSED		
	N	P	K	N	P	K
40-20-40	9.0a ¹	1.1b	10.0b	14.7	1.9	15.5c
60-30-60	20.1	2.5a	23.2a	23.1	3.3	26.7bc
80-40-80	11.9a	1.6ab	12.1b	32.1a	4.9	44.2a
80-40-80**	30.2	3.9	27.7a	32.8a	6.1	39.4ab
0-0-0	a	a	a	1.0	0.2	1.6

* Seeding Rate: 60 kg/ha

** Split applied

^aSample area yield too low for nutrient concentration analyses.

¹Means followed by a common letter in a column are not significantly different at five percent level (Duncan's Multiple Range Test). Mean value based on a sample size of three.

5. CONCLUSIONS

Comparisons between the legume and grass species tested indicated that plant cover achieved with the individual species improved progressively and stayed high during the maintenance fertilization phase except alsike clover, which had almost disappeared, and sweet clover, which had thinned out considerably. The virtual disappearance of alsike clover and the thinning out of sweet clover is attributed to their non-adaptability to the harsh mine micro-environment. The sweet clover, a biennial, reseeded itself in the first two years; the second natural reseeding (1982) was poor.

Most species produced higher plant cover and biomass and generally did better on spoil topdressed with a mineral soil than on spoil. Alfalfa, brome grass, creeping red fescue and Kentucky bluegrass appear to be the best adaptable species till the fifth year. Plant cover and biomass yields specifically of grasses species decreased and their quality deteriorated in the fifth year due to N deficiency and low level of P as maintenance fertilization was discontinued in that year. The good performance of the mix is attributable to the presence of alfalfa in the mix. It appears alfalfa should be included in seed mixes in the future for operational reclamation in similar environment.

In the factorial experiments involving seeding rate of a mix and fertilization, no plant growth took place of the spoil without fertilizer. Topdressing with a mineral soil without fertilizer aided some

plant growth but the cover and vigor were poor. A consistently significant increase in plant growth was achieved over the years when the spoil was topdressed with a mineral soil and fertilized annually.

A 80-40-80 fertilizer rate provided the best plant growth on both spoil and topdressed spoil. The differences between 80-40-80 single and split applications were not significant statistically.

Seeding rates varying from 30 to 120 kg/ha did not have any significant effects on the overall plant growth. The 60 kg/ha seems to be the optimum rate, but for economic reasons the 30 kg rate may be judged to be as effective.

In the fifth year, discontinuation of maintenance fertilization resulted in deficiency of available N and P in the growth media which caused a decline in plant growth, vigor and dry matter yields. It appears that the residual effects of fertilizer application to the spoil without topdressing with a mineral soil will not last more than two years.

LIST OF REFERENCES

- Average Analysis of Alberta Feeds, 1965-1975. 1977. Alberta Agriculture. Agricultural Soil and Feed Testing Laboratory, Edmonton.
- Bowser, W.E., 1967. Agro-climatic Areas of Alberta. Canada Department of Agriculture and Alberta Soil Survey, Edmonton.
- Brown, R.W. and R.S. Johnston. 1976. Revegetation of an Alpine Mine Disturbance: Beartooth Plateau, Montana. U.S. Forest Serv. Res. Not INT-206, Intermountain Forest and Range Exp. Sta., Ogden, Utah.
- _____. 1978. Rehabilitation of High Elevation Mine Disturbance. Proceedings: High Altitude Revegetation Workshop No. 3. Edited by S.T. Kenny. Colorado Water Resources Research Institute, Information Series No. 28. Colorado State University, Fort Collins, Colorado.
- Dumanski, J., T.M. Macyk, C.F. Veauvy and J.D. Lindsay. 1972. Soil Survey and Land Evaluation of the Hinton-Edson Area, Alberta.
- Johnston, R.S., R.W. Brown and J. Cavens. 1975. Acid Mine Rehabilitation Problems at High Elevations. Water-shed Manage. Symp. Am. Soc. Civil Eng., Utah State Univ., Logan.
- Lake, D. 1967. The Historical Geography of the Coal Branch. M. Sc. Thesis, University of Alberta, Edmonton.
- Lavkulich, L.M. 1981. Methods Manual. Pedology Laboratory, Department of Soil Science, University of British Columbia, Vancouver.
- Longley, R.N. 1970. Climatic Classification for Alberta Forestry, J.M. Powell and C.F. Nolasco, eds. Proceedings of the Third Forest Microclimate Symposium. Canadian Forest Service, Forest Research Laboratory, Calgary, Alberta.
- Powell, J.M. and D.C. MacIver. 1976. Summer Climate of the Hinton-Edson Area, West-Central Alberta, 1961-1970. Report NOR-X-149. Environ. Can., Can. For. Serv. Inform., Edmonton.

- Root, J.D. 1976. Physical Environment of an Abandoned Strip-Mine Near Cadomin, Alberta. Alberta Research Council Bull. No. 34., Edmonton.
- Row, J.S. 1972. Forest Regions of Canada. Environ. Can., Can. For. Serv. Publ. No. 1300.
- Russell, W.B. And S.K. Takyi. 1979. The Cadomin Reclamation Research Project: First Year Results (1978). ENR Report No. 121. Forest Service, Alberta Energy and Natural Resources, Edmonton.
- Takyi, S.K. 1980. Influence of Roll-Out Mats and Ridging on the Establishment of Plant Cover on an Unamended Coal Spoil; A Progress Report for 1979. ENR Report No. 152. Forest Service, Alberta Energy and Natural Resources, Edmonton.
- Takyi, S.K. and R.H. Leitch. 1981. Influence of Roll-Out Mats and Ridging on the Establishment of Plant Cover on an Unamended Coal Spoil; A Progress Report for 1980. ENR Report No. T/20-80. Forest Service, Alberta Energy and Natural Resources, Edmonton.
- Takyi, S.K. and W.B. Russell. 1980. The Cadomin Reclamation Research Project: Second Year Result (1979). ENR Report No. 155. Forest Service, Alberta Energy and Natural Resources, Edmonton.